Study of the ^{19}Ne spectroscopic properties of astrophysical interest via a new method of inelastic scattering (November 2013)

Florent Boulay (GANIL, France)

Nova Del 2013

1) Astrophysical motivations (Nova)

2) The experiment and preliminary results (Inelastic scattering of ^{19}Ne)

3) Angular distribution

Picturing by François De Oliveira

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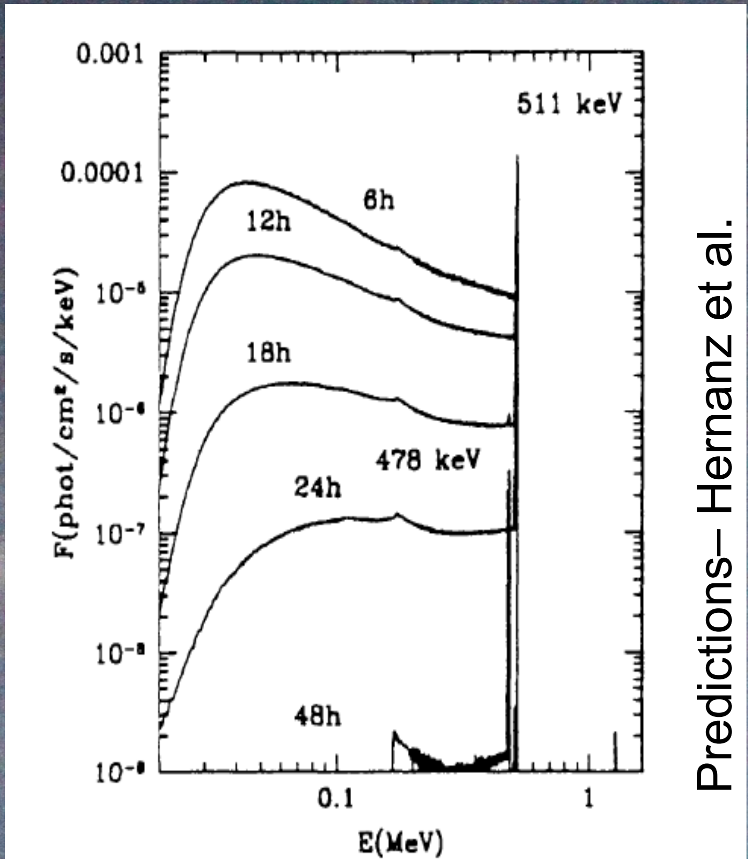

Predictions– Hernanz et al.

- A key observable: Gamma rays at 511 keV
- One of the main β+ emitters: ^{18}F
- 2 main reactions constrain the abundance of ^{18}F: ^{18}F(p,α)^{15}O et ^{18}F(p,γ)^{19}Ne.
- Study of ^{18}F via ^{19}Ne.

b) Knowledge about ^{19}Ne

(Gamow Window 300 GK)

No	E_x [a] (MeV)	J^{π} [b]	Γ_{γ} [c] (eV)	Γ_p [d] (keV)	Γ_{α} [e] (keV)
1	6.419	$(\frac{3}{2}^{+})$	0.77(41)	2.2(4)E−37	0.27(27)
2	(6.422)	$(\frac{11}{2}^{+})$	0.35(18)	1.8(18)E−38	20(14)E−3
3	6.437	$\frac{1}{2}^{-}$	[1(1)]	1.1(11)E−20	220(20) (M)
4	6.449	$(\frac{3}{2}^{+})$	1.1(6)	4(4)E−15	1.3(10)
5	(6.504)	$(\frac{7}{2}^{+})$	0.14(8)	4.6(46)E−10	0.4(4)
6	(6.542)	$(\frac{9}{2}^{+})$	0.30(16)	2.7(27)E−12	1.3(11)E−2
7	6.698	$(\frac{5}{2}^{+})$	0.29(15)	1.2(12)E−5	1.2(10)
8	6.741	$\frac{3}{2}^{-}$	5.0(26)	2.22(69)E−3	5.2(37)
9	(6.841)	$(\frac{3}{2}^{-})$	2.8(15)	9.7(97)E−3	25(18)
10	6.861	$\frac{7}{2}^{-}$	2.3(12)	1.1(11)E−5	1.2(0.9)
11	(6.939)	$(\frac{1}{2}^{-})$	[1(1)]	3.4(34)E−2	99(69)
12	(7.054)	$(\frac{5}{2}^{+})$	[1(1)]	4.7(47)E−2	29(25)
13	7.0757	$\frac{3}{2}^{+}$	[1(1)]	15.2(1)	23.8(12) (M)
14	7.173	$(\frac{11}{2}^{-})$	0.15(8)	9.8(98)E−8	1.2(10)E−2
15	7.238	$\frac{3}{2}^{+}$	[1(1)]	0.35(35)	6.0(52)

Values C. D. Nesaraja *et al.(2007)*

b) Knowledge about ^{19}Ne

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(Gamow Window 300 GK)

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b) Knowledge about ^{19}Ne

A. M. Laird *et al* PRL (2012) : $^{19}F(^3He,t)^{19}Ne$.

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Controversery on 3/2 states

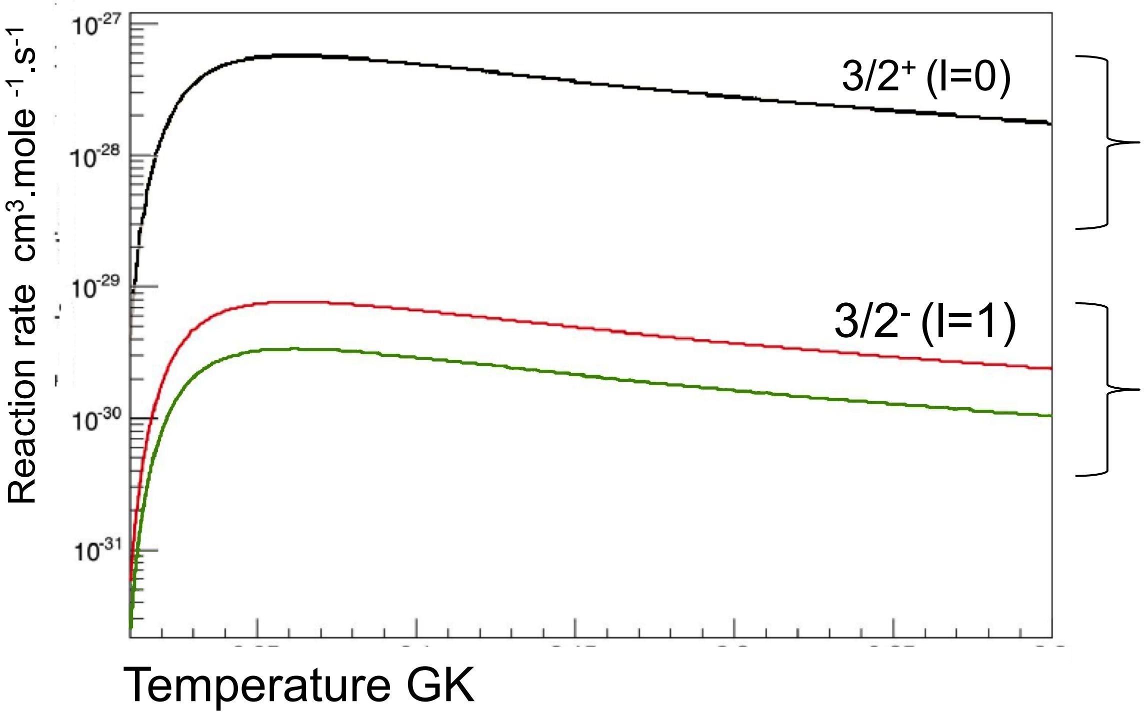
(Gamow Window 300 GK)

D. J. Mountford *et al.* PRC (2012) : $^{18}F(p,\alpha)^{19}Ne$ @ 3.924MeV/u

Values C. D. Nesaraja *et al.(2007)*

c) An example : the resonant state at 8 keV

Reaction rate for resonant state at 8 keV of the reaction $^{18}F(p,\alpha)^{15}O$



S. Utku et al. (1998)
Angular momentum l=0

controversy

Adekola et al. (2009)
Angular momentum l=1

F. Boulay Master Thesis (2012)

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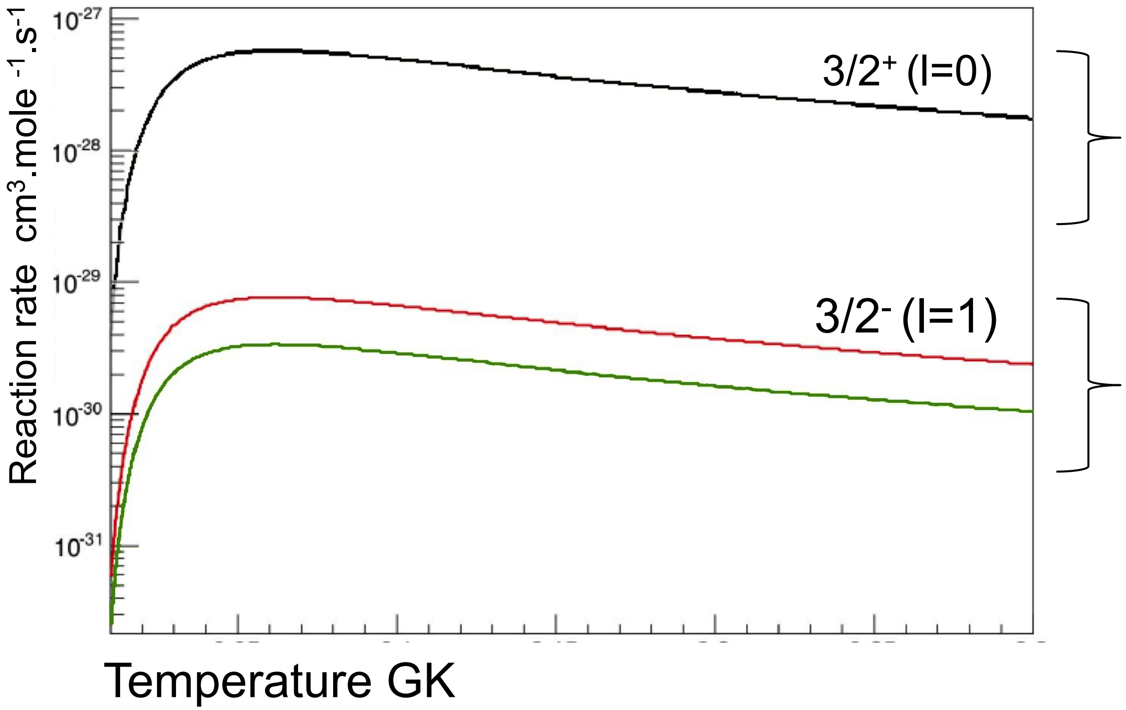

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Angular momentum l=0

controversy

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Angular momentum l=1

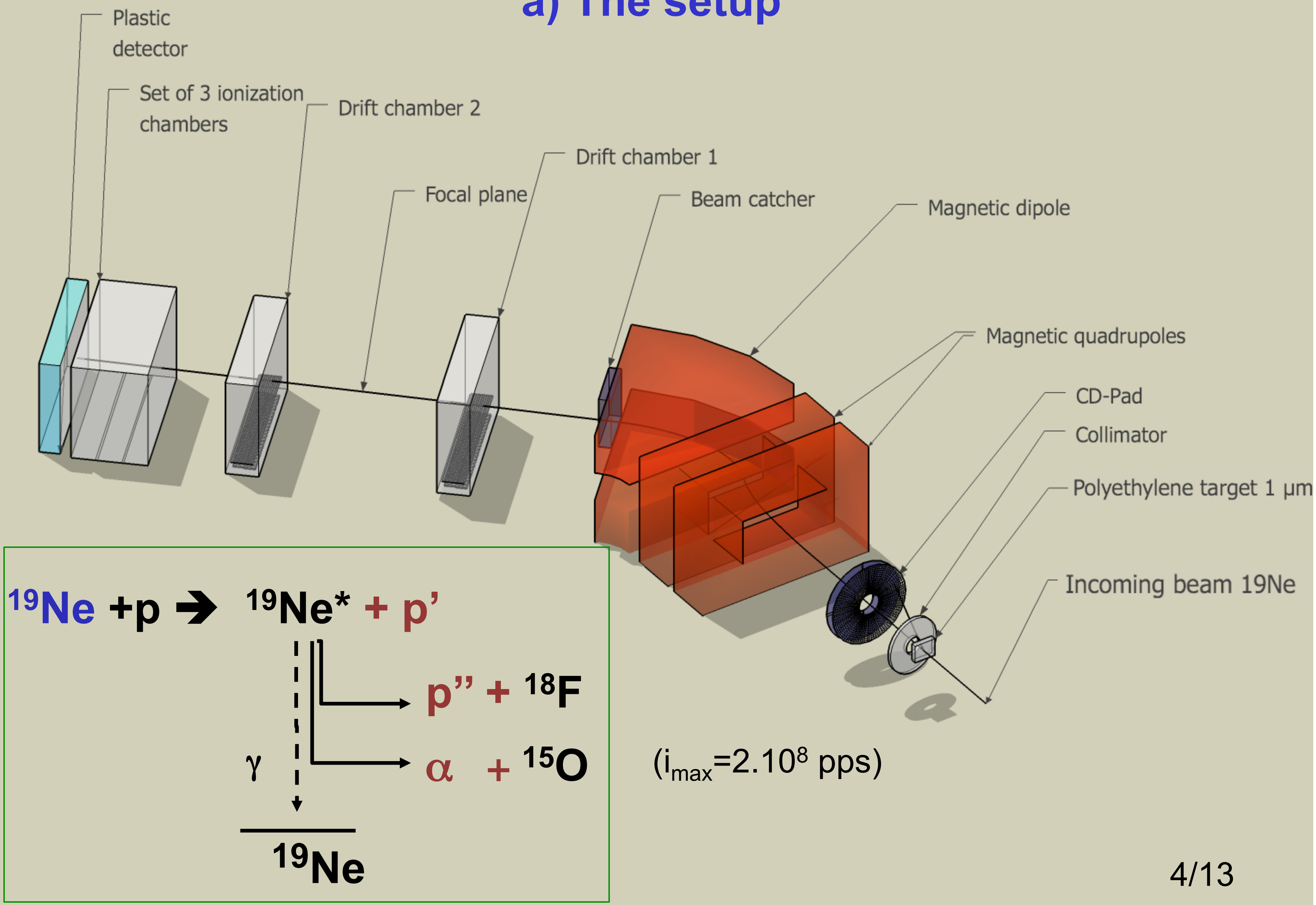
=> We do need to measure experimentally the spectroscopic properties of ^{19}Ne

F. Boulay Master Thesis (2012)

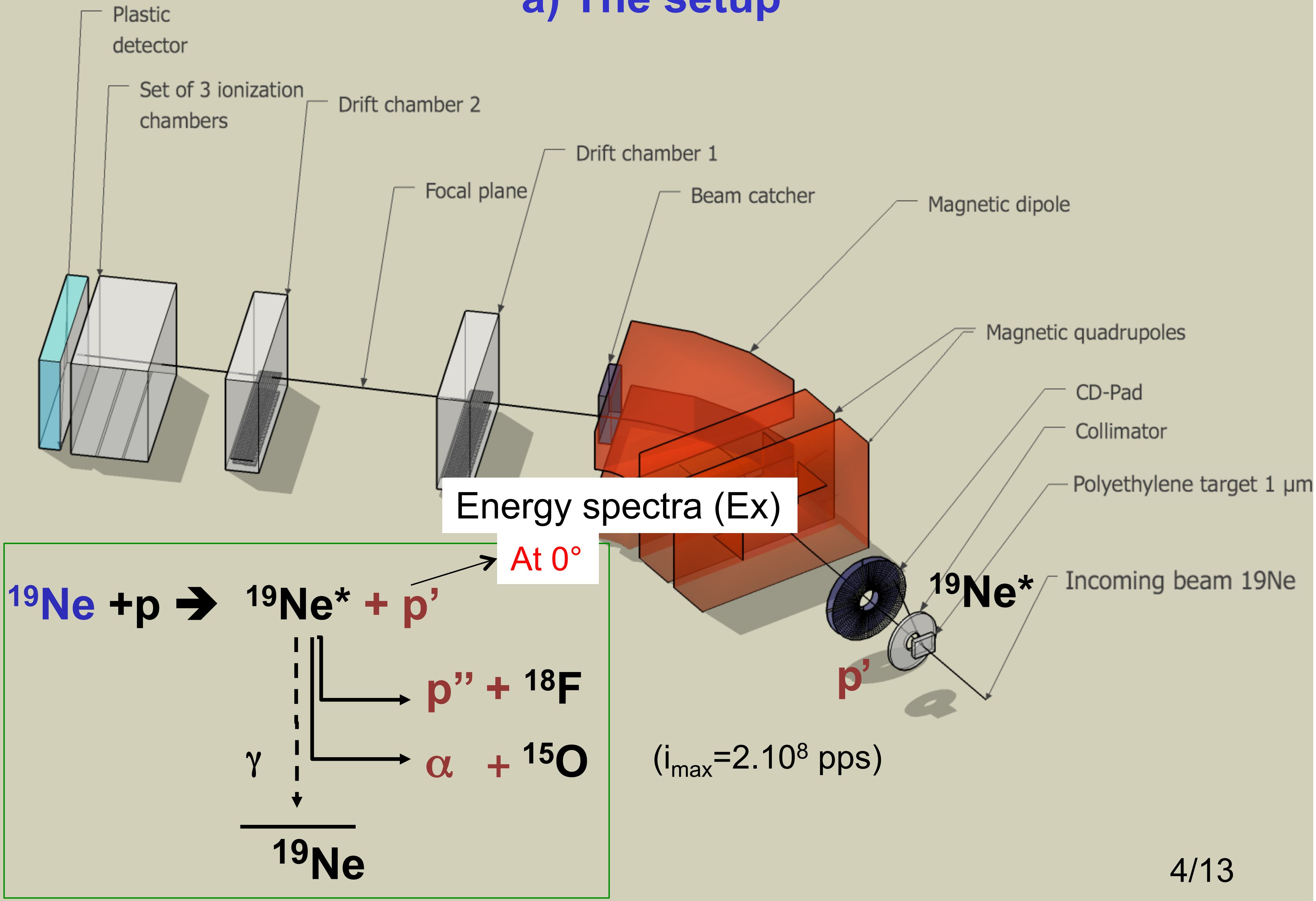
The e641s experiment at GANIL

November 2013

a) The setup


Plastic detector
Set of 3 ionization chambers
Drift chamber 2
Focal plane
Drift chamber 1
Beam catcher
Magnetic dipole
Magnetic quadrupoles
CD-Pad
Collimator
Polyethylene target 1 μm
Incoming beam 19Ne
^{19}Ne +p → ^{19}Ne* + p'
p'' + ^{18}F
α + ^{15}O
γ
^{19}Ne
(i_{max}=2.10^8 pps)

a) The setup



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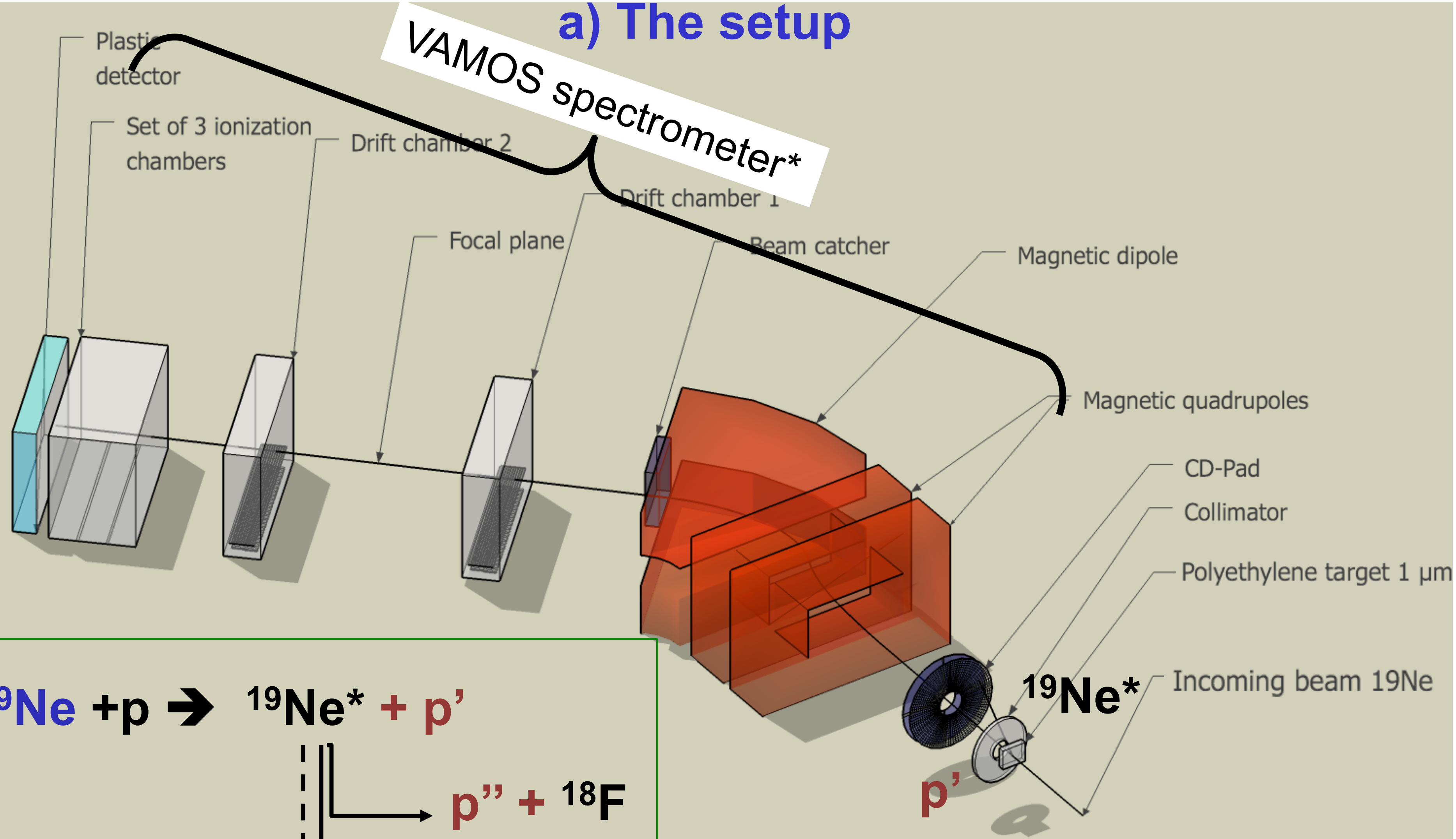

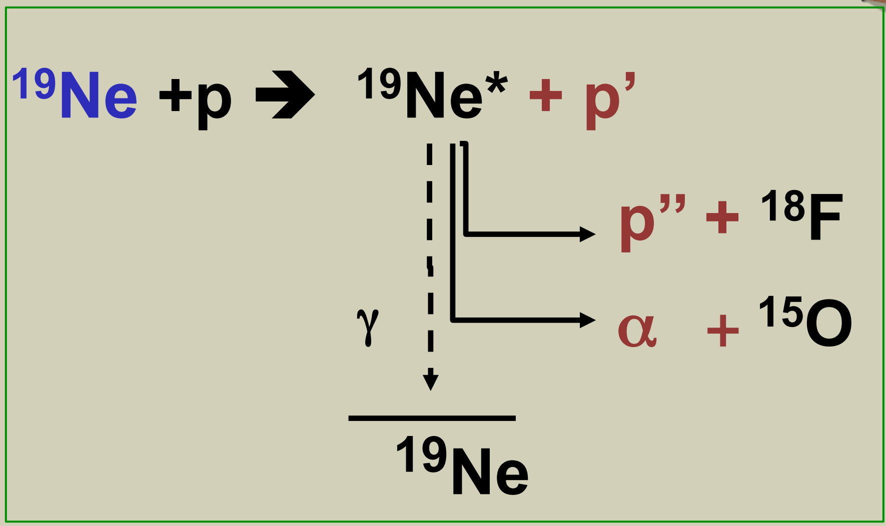

(i_{max}=2.10^{8} pps)

*M. Rejmund *et al.* NIMA (2011)

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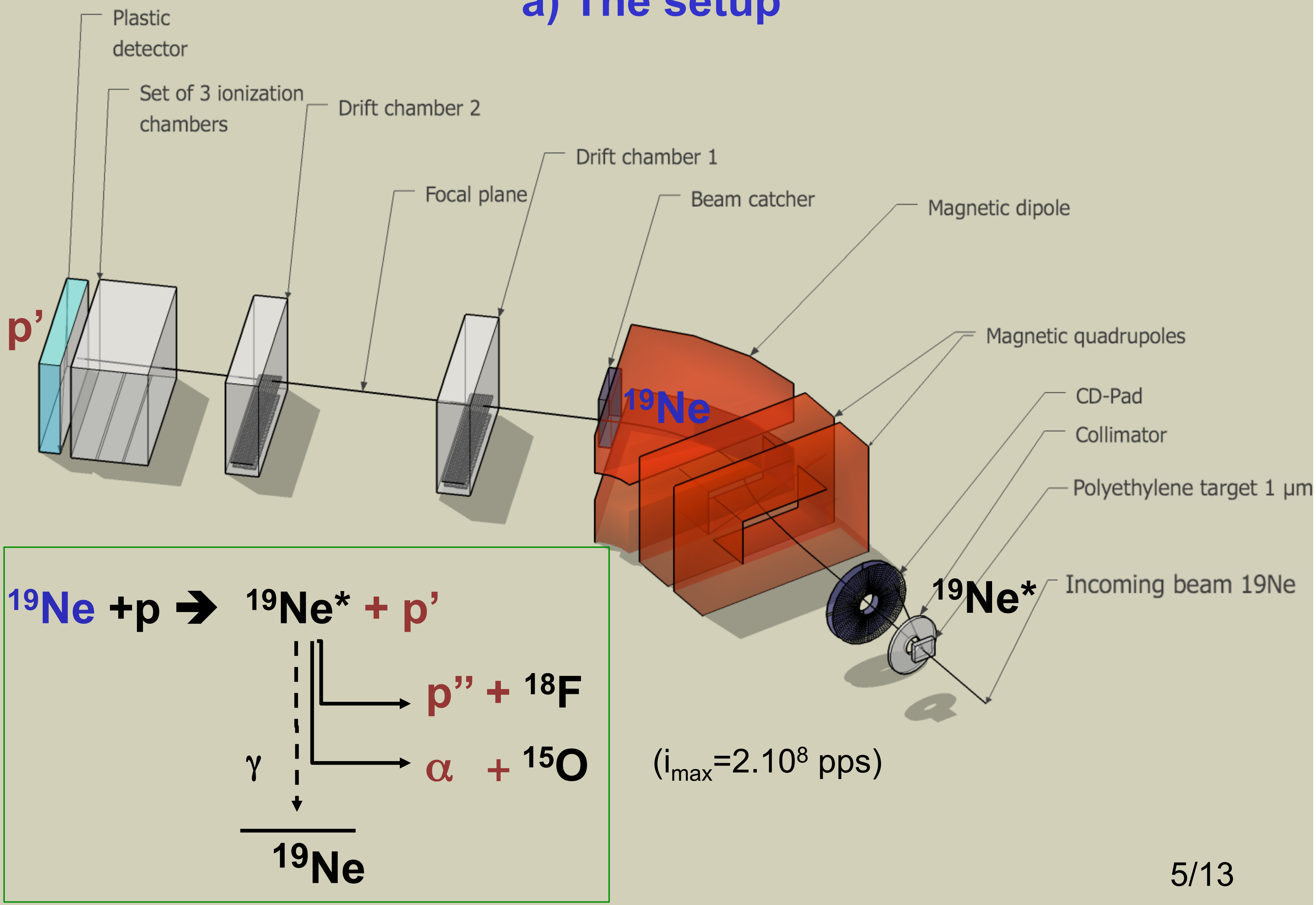
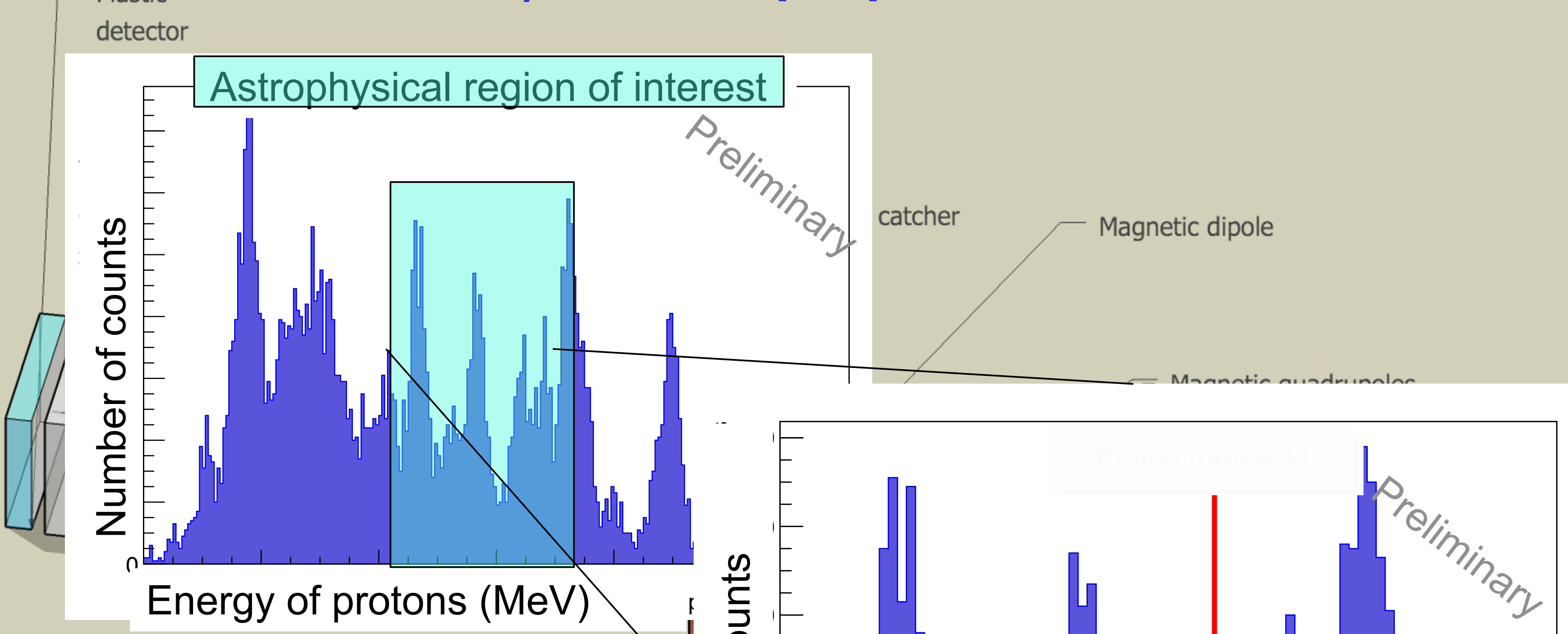
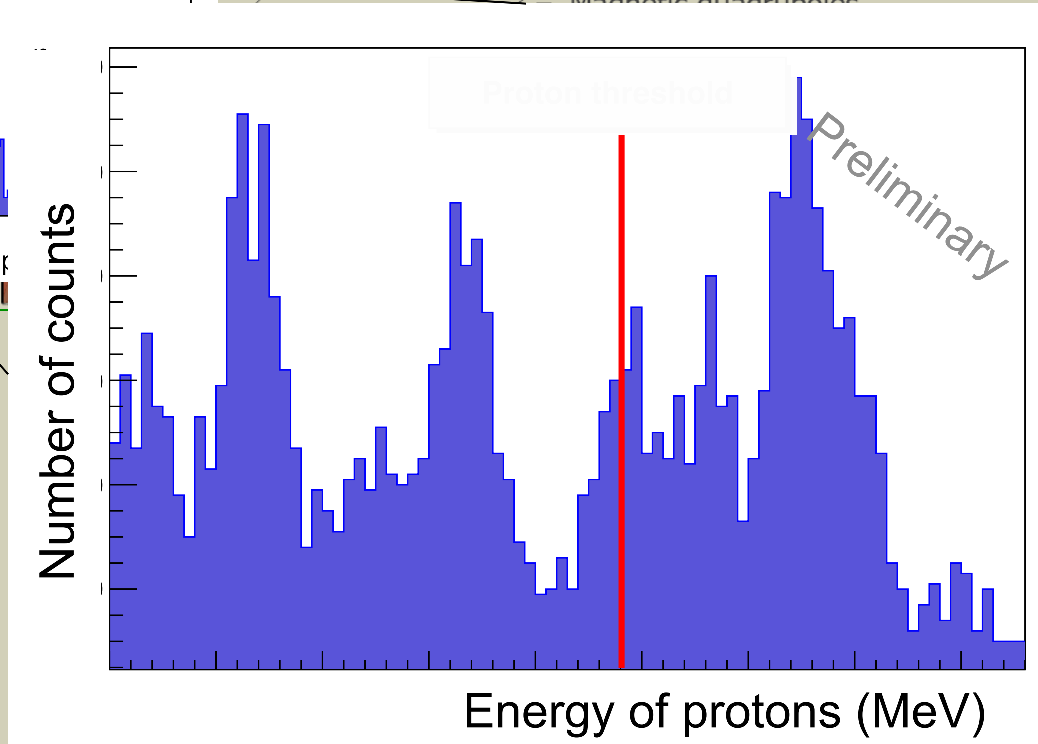
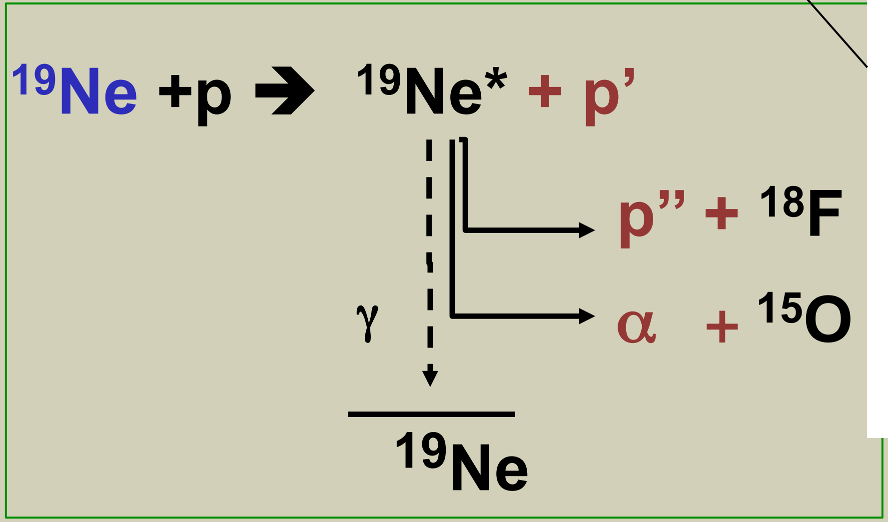


(i_{max}=2.10^8 pps)

b) Protons p' spectra

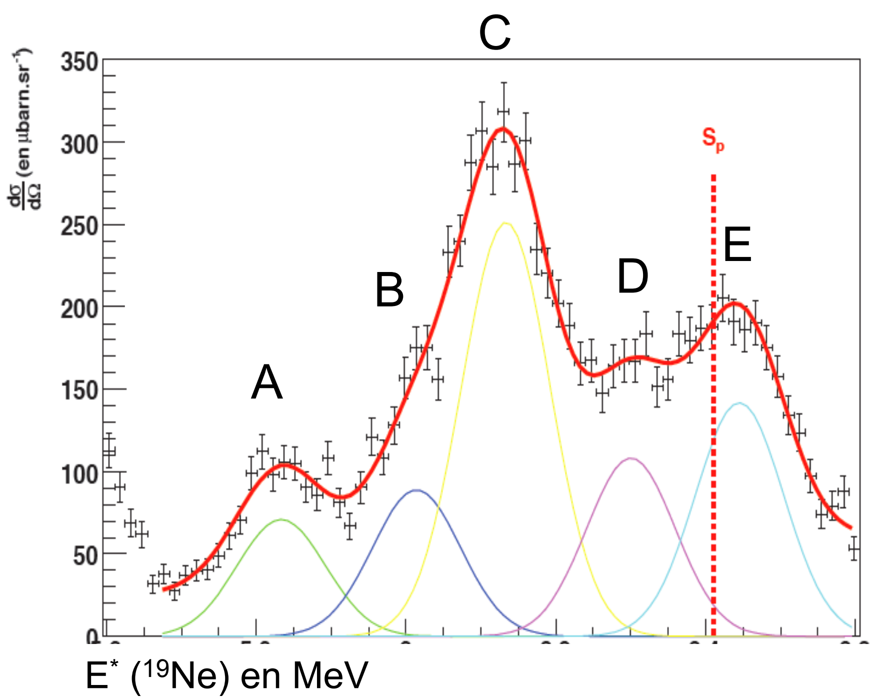


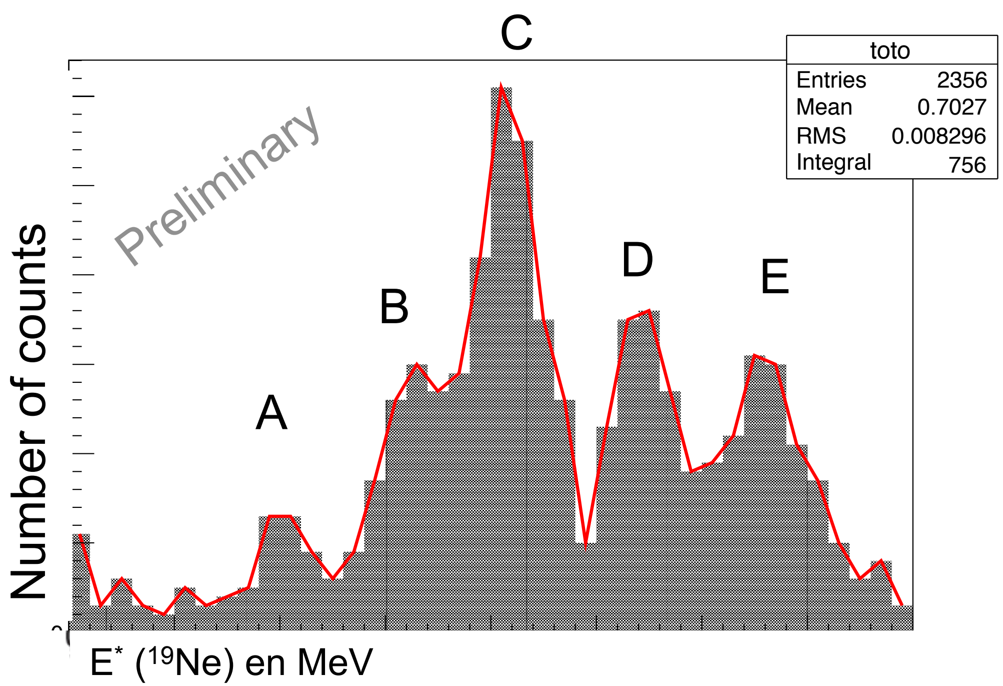




c) ^{19}Ne* exitation energy spectra

Comparison in the range of excitation energy of ^{19}Ne* (5.6 MeV and 6.6 MeV)





Ph.D JC Dalouzy

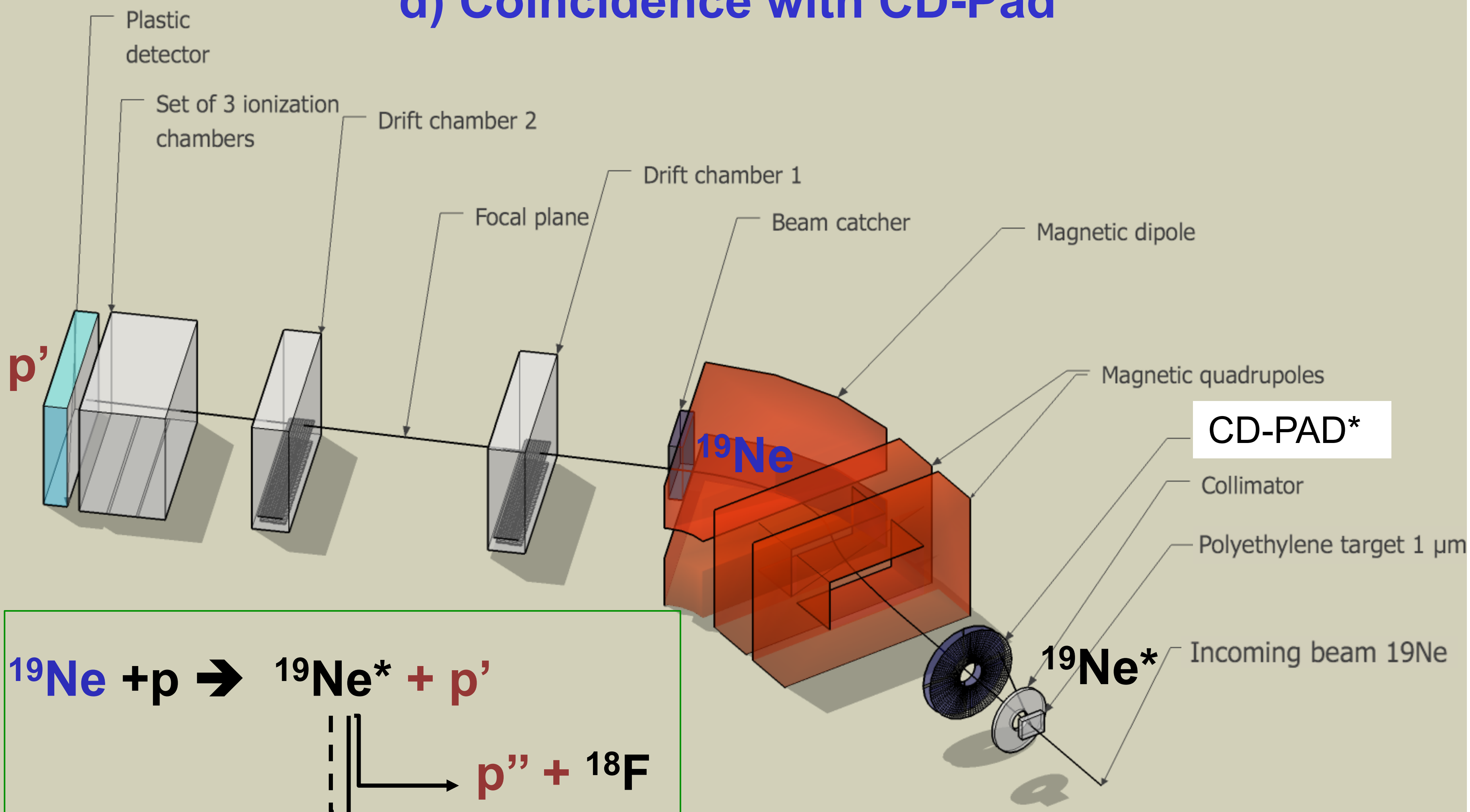
Resolution in excitation energy
140 keV

This experiment

Resolution in excitation energy
around 80 keV

Improvement in resolution by a factor ~2 with the new method !!!!!

d) Coincidence with CD-Pad



$^{19}Ne + p \rightarrow {}^{19}Ne^* + p'$

- $^{19}Ne^* \rightarrow p'' + {}^{18}F$
- $^{19}Ne^* \rightarrow \alpha + {}^{15}O$
- $^{19}Ne^* \xrightarrow{\gamma} {}^{19}Ne$

*T. Davinson *et al.* NIMA 454(2000)

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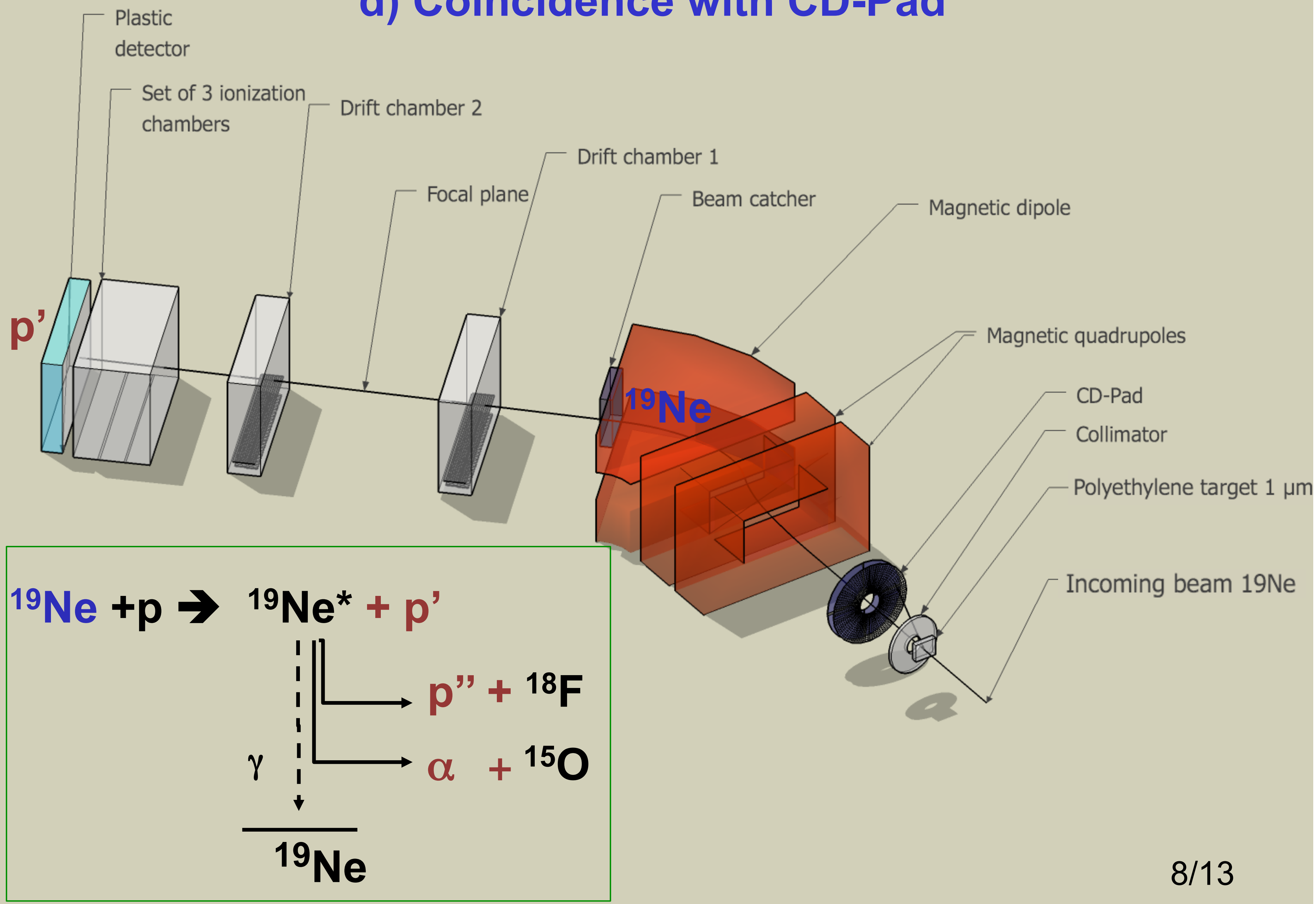

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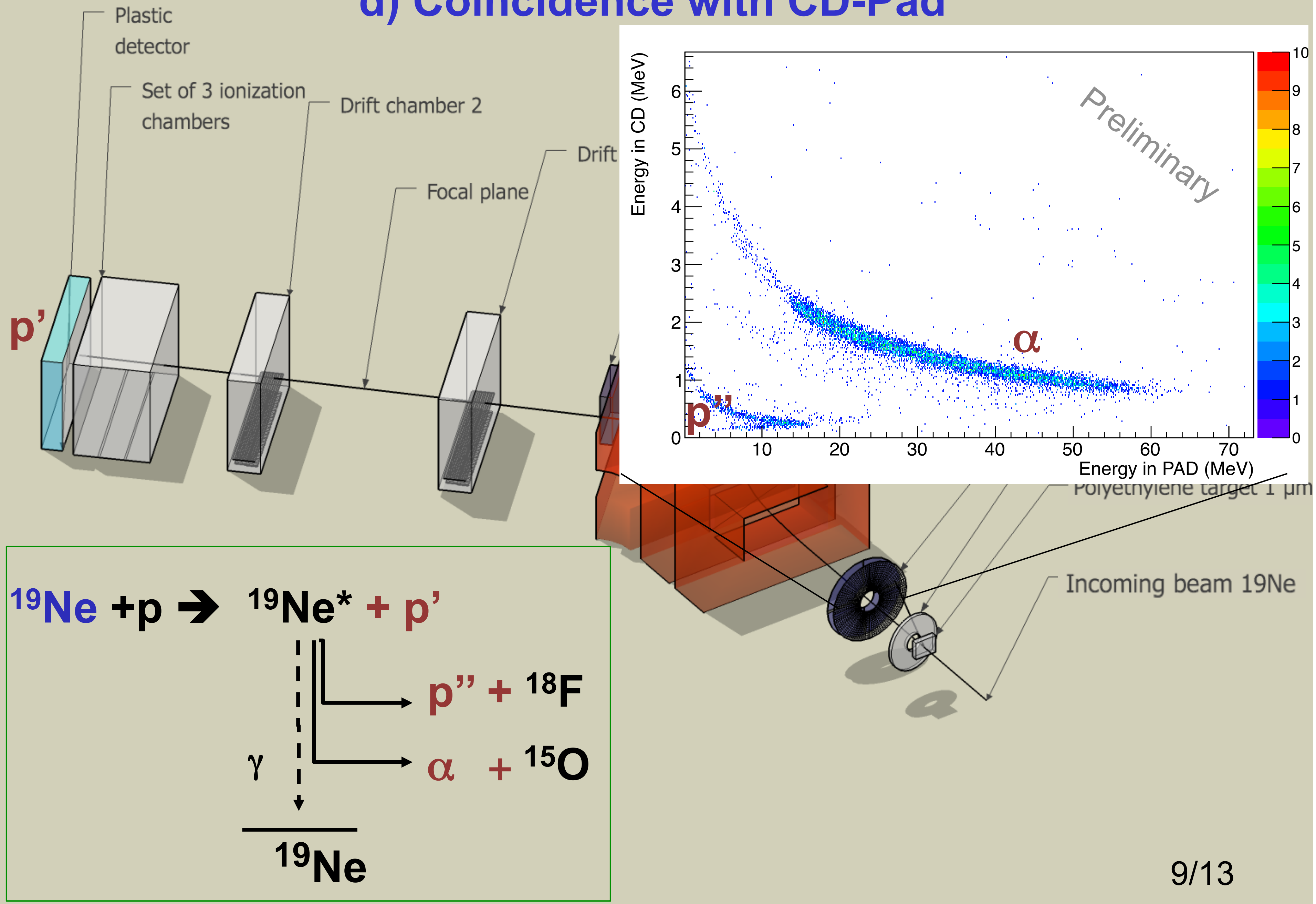

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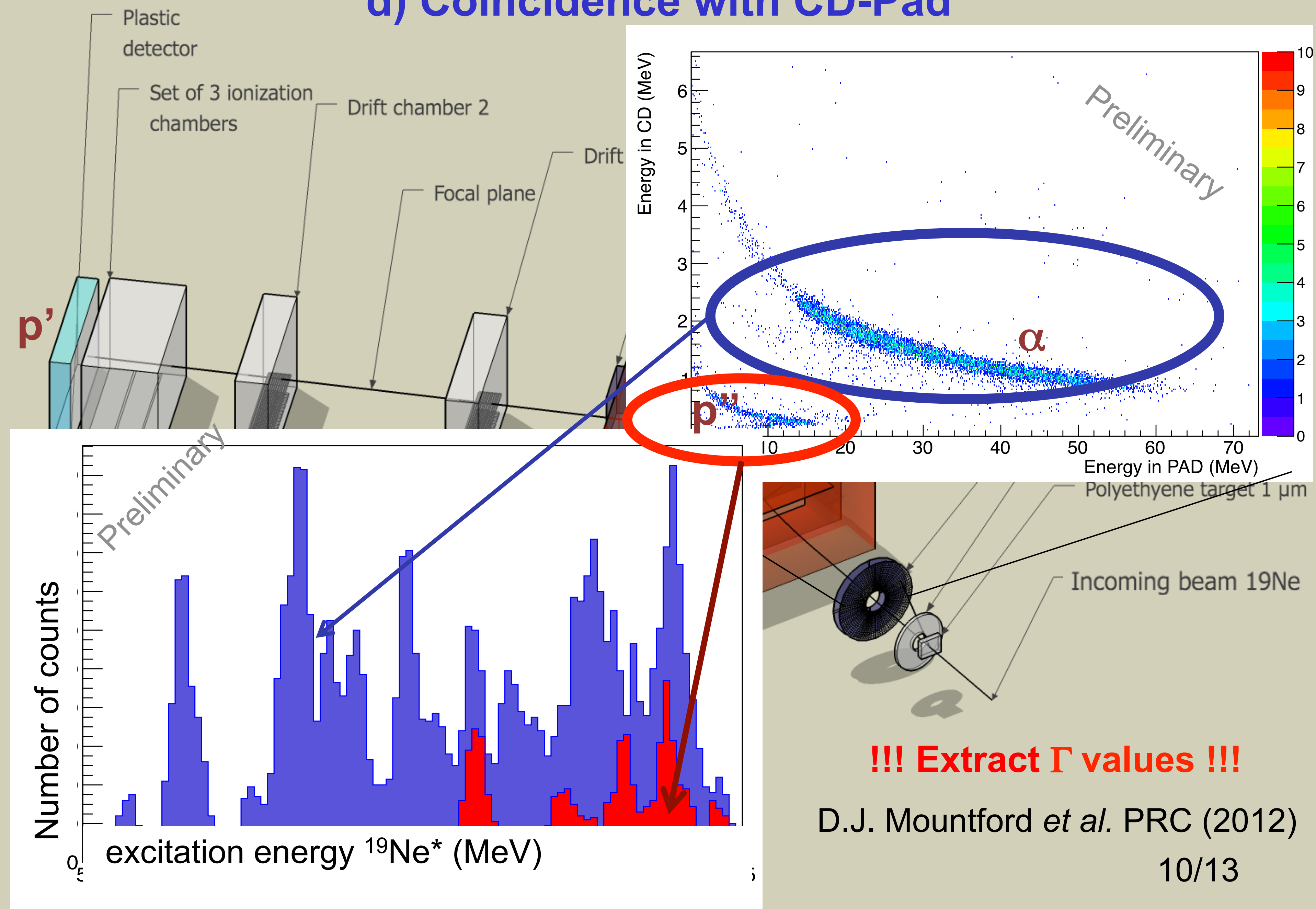
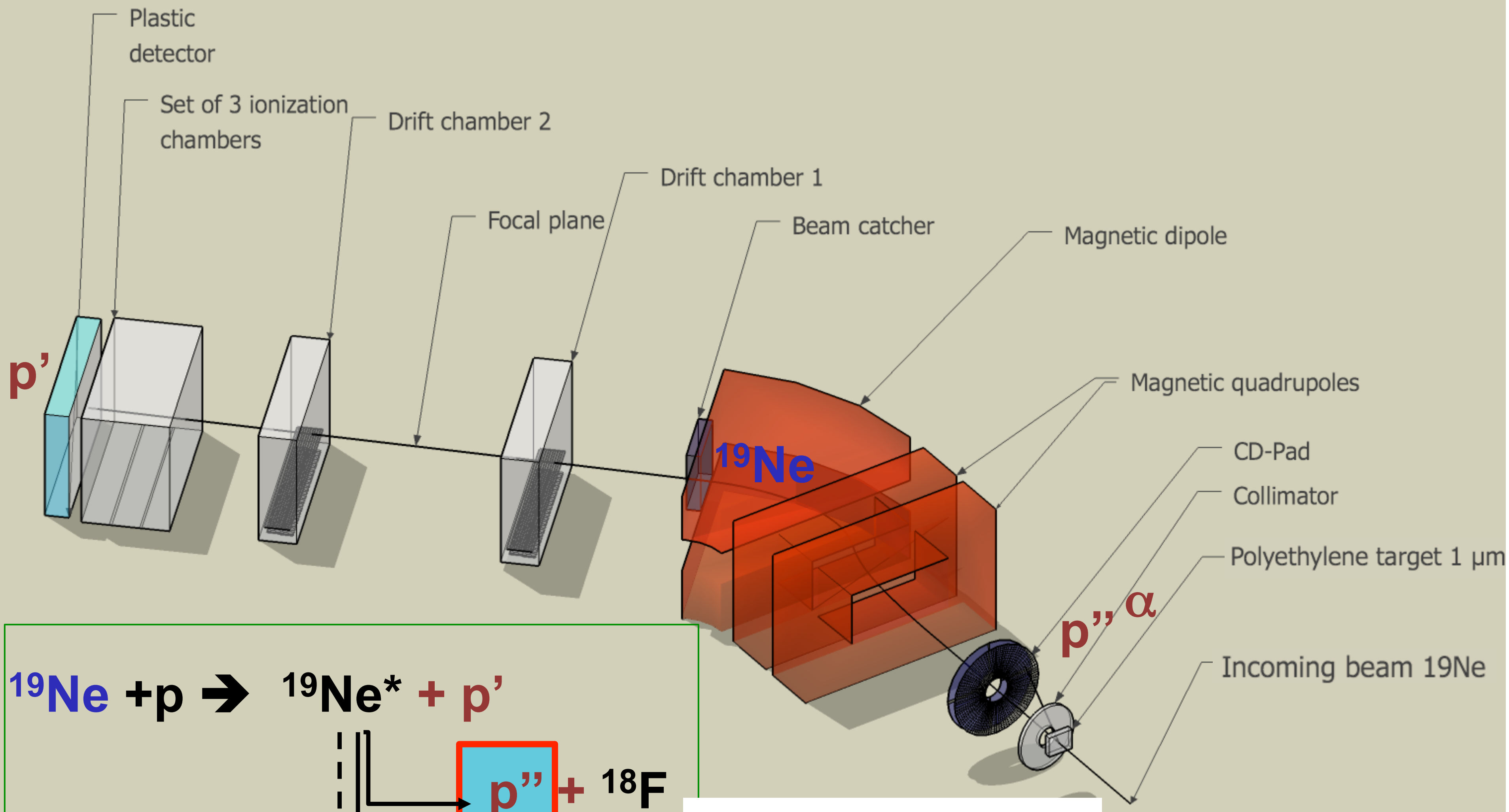
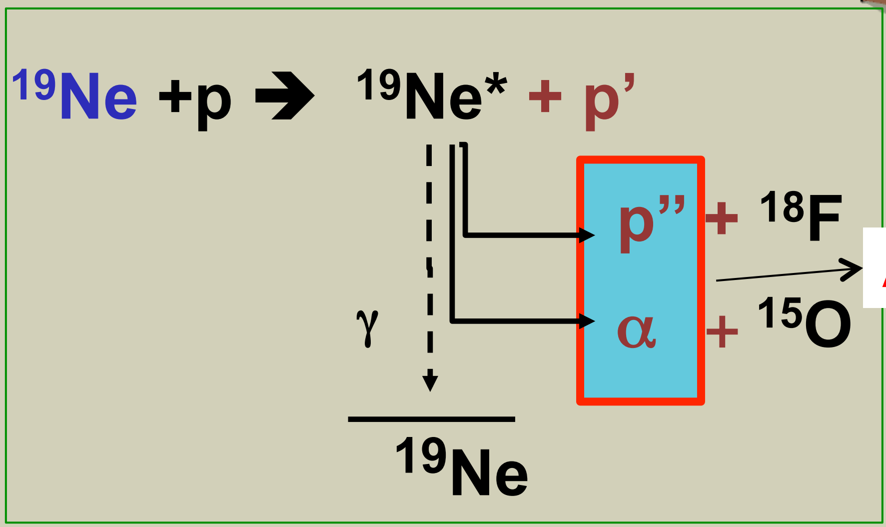


!!! Extract Γ values !!!

D.J. Mountford *et al.* PRC (2012)





Angular distributions

Spin of the state

⇒ Model independant

J.G. Pronko and R.A. Lindgren
Nuclear Instruments and Methods (1972)

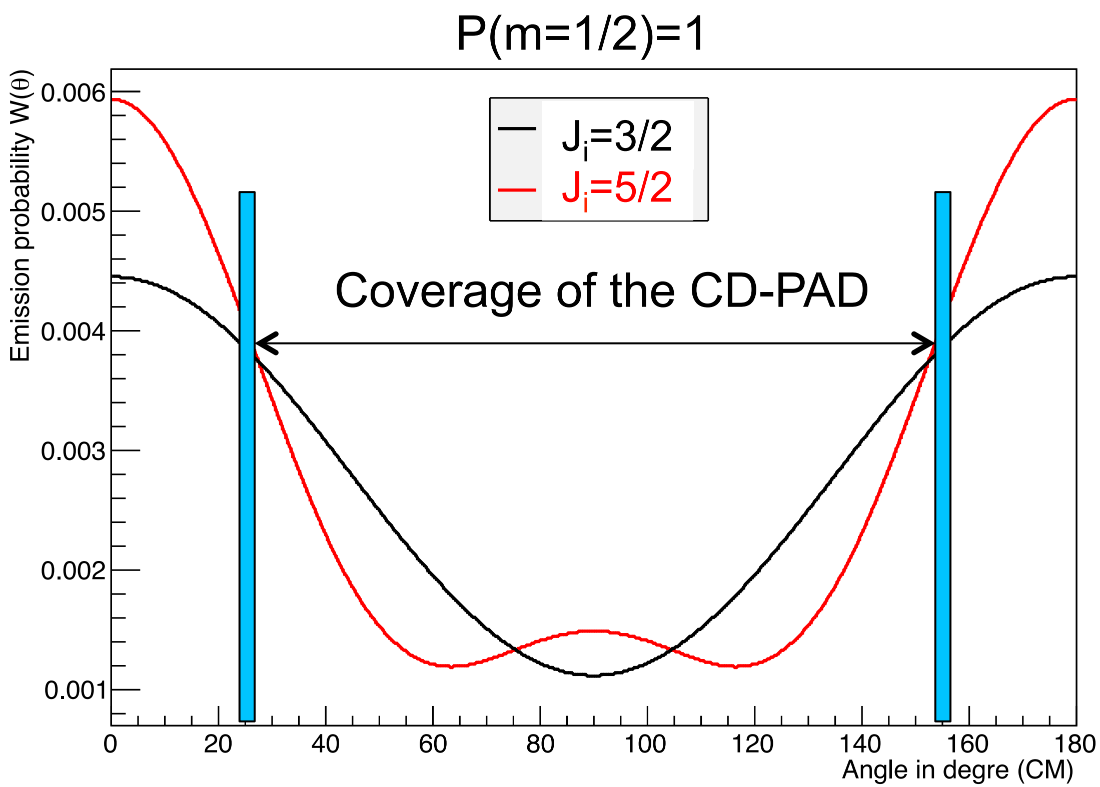
$^{19}Ne^* \rightarrow \alpha + {}^{15}O$

$$W(\theta) = \sum_{mK} P(m)\, A(Jll'\,smK)\, Q_K\, P_K(\cos\theta)$$

→ with K=min(l+l',2J_i) ⟶ Spin

where

$$A(Jll'\,smK) = (-1)^{|s-m|}\, \hat{l}\hat{l}'\, \hat{J}^2 (ll'00|K0) \times (JJm-m|K0)\, W(lJl'J;\, sK)$$



Conclusion

Experiment

Online analysis : experiment is successful! ✓
(range of interest covered with good statistics…)

The resolution is better with this new inelastic scattering method. ✓

Access to spin and widths in a model independent way ✓

About the fine analysis

Study of angular correlation theory ✓

Starting of the analysis of the CD-PAD data laboratoire commun CEA/DSM CNRS/IN2P3

Thank you for your attention

A big thank to the collaboration !!!

GANIL (France) : F. Boulay, B. Bastin, F. De Oliveira, A. Lemasson, M. Rejmund, C. Schmitt, B. Jacquot, O. Kamalou, A.M. Sanchez Benitez, E. Traykov, C. Rodriguez, J. Grinyer, O. Sorlin, J.-C. Thomas and P. Delahaye.
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IPN Orsay (France) : N. de Séréville.
University of Huelva (Spain) : G. Marquinez Duran and L. A. Acosta Sanchez.
LPC Caen (France) : L. Achouri.
Vinca Institute (Serbia) : P. Ujic.
Rez (Czech Republic) : J. Mrazek.
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